

What is claimed is:

1. A recursive discrete Fourier transformation device
wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1),$
5 $x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N
is a positive integer which is 1 or more) each having an equal
interval are supplied and as complex Fourier coefficients under
degree k (k is 0 or a positive integer smaller than N) obtained
by, with such N data values supplied since time t as a data
10 stream, carrying out complex Fourier transformation on the
data stream, a real part $X_r(k, t)$ and an imaginary part $X_i(k,$
 $t)$ are obtained, the discrete Fourier transformation device
comprising:

a first temporary storage means for storing the data
15 stream $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1)$ supplied
since time t at time $t+N-1$ temporarily;

a discrete Fourier operation means for obtaining the
complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ of the data
stream stored temporarily in the first storage means; and
20 a second temporary storage means for storing the complex
Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ obtained by the
discrete Fourier operation means,

the discrete Fourier operation means including:

a subtracting portion for obtaining a data value
25 of a difference between a data value $x(t+N)$ supplied at time
 $t+N$ and a data value $x(t)$ memorized temporarily in the first
storage means;

a constant multiplying portion for obtaining a
signal with a predetermined amplitude by multiplying the
30 obtained data value of the difference with a positive constant
value A for giving a predetermined amplitude;

an adder portion for obtaining a summed signal
by summing the signal with the predetermined amplitude obtained
from the constant multiplying portion and one of the real part
35 $X_r(k, t)$ and the imaginary part $X_i(k, t)$ of the complex Fourier
coefficients stored temporarily in the second temporary

storage means; and

a basic function arithmetic processing portion
for receiving the summed signal obtained from the adder portion
and the other of the real part $X_r(k, t)$ and the imaginary part
5 $X_i(k, t)$ of the complex Fourier coefficients stored temporarily
in the second temporary storage means and carrying out an
arithmetic operation on the received signals using a constant
based on a basic frequency thereby to obtain the complex Fourier
coefficients $X_r(k, t+1)$ and $X_i(k, t+1)$ at time $t+1$.

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2. A recursive discrete Fourier transformation device
as claimed in claim 1 wherein the positive constant value A
for providing with an amplitude corresponding to a difference
between the $x(t+N)$ and the $x(t)$ is capable of being set
15 selectively with 1, square root of N or $1/N$.

3. A recursive discrete Fourier transformation device
wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1),$
 $x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N
20 is a positive integer which is 1 or more) each having an equal
interval are supplied and as complex Fourier coefficients under
degree k (k is 0 or a positive integer smaller than N) obtained
by, with such N data values supplied since time t as a data
stream, carrying out complex Fourier transformation on the
25 data stream, a real part $X_r(k, t)$ and an imaginary part $X_i(k, t)$ are obtained,
the discrete Fourier transformation device comprising:

a first temporary storage means for storing the data
stream $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1)$ supplied
30 since time t at time $t+N-1$ temporarily;

a discrete Fourier operation means for obtaining the
complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ of the data
stream stored temporarily in the first storage means; and

35 a second temporary storage means for storing the complex
Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ obtained by the
discrete Fourier operation means,

wherein the discrete Fourier operation means obtains complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ according to following equations.

$$X_r(k, t+1) = \left\{ X_r(k, t) + \frac{1}{A} [x(t+N) - x(t)] \right\} \times \cos\left[2\frac{\pi k}{N}\right] + X_i(k, t) \sin\left[2\frac{\pi k}{N}\right]$$

5 $X_i(k, t+1) = X_i(k, t) \cos\left[2\frac{\pi k}{N}\right] - \left\{ X_r(k, t) + \frac{1}{A} [x(t+N) - x(t)] \right\} \sin\left[2\frac{\pi k}{N}\right]$

where, A is a positive constant value for providing $[x(t+N) - x(t)]$ with an amplitude.

4. A recursive discrete Fourier transformation device
10 as claimed in claim 3 wherein the positive constant value A
for providing with an amplitude corresponding to a difference
between the $x(t+N)$ and the $x(t)$ is capable of being set
selectively with 1, square root of N or 1/N.

15 5. A recursive discrete Fourier transformation device
wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1),$
 $x(t+N)$ sampled at times t, t+1, t+2, t+3, ..., t+N-1, t+N (N
is a positive integer which is 1 or more) each having an equal
interval are supplied and with such N data values supplied
20 since time t as a data stream, complex Fourier transformation
is carried out to the data stream using a plurality of degrees
k (k is 0 or a positive integer smaller than N) so as to obtain
real parts $X_r(k, t)$ and imaginary parts $X_i(k, t)$ as plural
sets of complex Fourier coefficients, the discrete Fourier
25 transformation device comprising:

a first temporary storage means for storing the data
stream $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1)$ supplied
since time t at time t+N-1 temporarily;

30 plural discrete Fourier operation means for obtaining
the complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ for
the data stream stored temporarily in the first storage means

for each of plural k values; and

a second temporary storage means for storing each set of the complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ obtained by the plural discrete Fourier operation means corresponding to each k value,

the discrete Fourier operation means including:

a subtracting portion for obtaining a data value of a difference between a data value $x(t+N)$ supplied at time $t+N$ and a data value $x(t)$ memorized temporarily in the first storage means;

a constant multiplying portion for obtaining a signal with a predetermined amplitude by multiplying the data value of the difference obtained by the subtracting portion with a positive constant value A for giving a predetermined amplitude;

an adder portion for obtaining a summed signal by summing the signal with the predetermined amplitude obtained from the constant multiplying portion and one of a real part $X_r(k, t)$ and an imaginary part (k, t) of the complex Fourier coefficients stored temporarily by the second temporary storage means; and

a basic function arithmetic processing portion for receiving the summed signal obtained from the adder portion and the other of the real part $X_r(k, t)$ and the imaginary part (k, t) of the complex Fourier coefficients stored temporarily in the second temporary storage means and carrying out an arithmetic operation on the received signals using a constant based on a basic frequency thereby to obtain complex Fourier coefficients $X_r(k, t+1)$ and $X_i(k, t+1)$ at time $t+1$.

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6. A recursive discrete Fourier transformation device as claimed in claim 5 wherein the quantity of the degrees k is N.

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7. A recursive discrete Fourier transformation device as claimed in claim 5 wherein the positive constant value A

for providing with an amplitude corresponding to a difference between the $x(t+N)$ and the $x(t)$ is capable of being set selectively with 1, square root of N or $1/N$.

5 8. A recursive discrete Fourier transformation device where in data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1), x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N is a positive integer which is 1 or more) each having an equal interval are supplied and with such N data values supplied
10 since time t as a data stream, complex Fourier transformation is carried out to the data stream using a plurality of degrees k (k is 0 or a positive integer smaller than N) so as to obtain real parts $X_r(k, t)$ and imaginary parts $X_i(k, t)$ as plural sets of complex Fourier coefficients, the discrete Fourier
15 transformation device comprising:

 a first temporary storage means for storing the data stream $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1)$ supplied since time t at time $t+N-1$ temporarily;

20 plural discrete Fourier operation means for obtaining the complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ for the data stream stored temporarily in the first storage means for each of plural k values; and

25 a second temporary storage means for storing each set of complex Fourier coefficients $X_r(k, t)$ and $X_i(k, t)$ obtained by the plural discrete Fourier operation means corresponding to each k value,

 the discrete Fourier operation means including:

30 a common subtracting portion for obtaining a data value of a difference between a data value $x(t+N)$ supplied at time $t+N$ and a data value $x(t)$ memorized temporarily in the first storage means;

35 a common constant multiplying portion for obtaining a signal with a predetermined amplitude by multiplying the data value of the difference obtained by the common subtracting portion with a positive constant value A for giving a predetermined amplitude;

an adder portion for obtaining a summed signal by summing the signal with the predetermined amplitude obtained from the common constant multiplying portion and one of a real part $X_r(k, t)$ and an imaginary part (k, t) of the complex Fourier coefficients stored temporarily in the second temporary storage means; and

a basic function arithmetic processing portion for receiving the summed signal obtained from the adder portion and the other of the real part $X_r(k, t)$ and the imaginary part $X_i(k, t)$ of the complex Fourier coefficients stored temporarily in the second temporary storage means and carrying out an arithmetic operation on the received signals using a constant based on a basic frequency thereby to obtain the complex Fourier coefficients $X_r(k, t+1)$ and $X_i(k, t+1)$ at time $t+1$.

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9. A recursive discrete Fourier transformation device as claimed in claim 8 wherein the quantity of the degrees k is N .

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10. A recursive discrete Fourier transformation device as claimed in claim 8 wherein the positive constant value A for providing with an amplitude corresponding to a difference between the $x(t+N)$ and the $x(t)$ is capable of being set selectively with 1, square root of N or $1/N$.

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11. A recursive discrete Fourier transformation device wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1), x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N is a positive integer which is 1 or more) each having an equal interval are supplied and as a complex Fourier coefficient under degree k (k is 0 or a positive integer smaller than N) obtained by, with such N data values supplied since time t as a data stream, carrying out complex Fourier transformation on the data stream, a real part $X_r(k, t)$ and an imaginary part $X_i(k, t)$ are obtained, the discrete Fourier transformation device comprising:

a data updating means for obtaining a first subtraction signal by subtracting data $x(t)$ supplied before N sampling period from data $x(t+N)$ supplied at time $t+N$;

5 a recursive processing means for obtaining a new second subtraction signal by subtracting an addition signal generated recursively using an already generated second subtraction signal from the obtained first subtraction signal; and

10 a multiplying means for obtaining the real part $X_r(k, t)$ of the Fourier coefficients by summing up a signal obtained by multiplying the new second subtraction signal obtained by the recursive processing means with a first constant value and a signal obtained by multiplying the second subtraction signal supplied before a sampling period with a second constant value and for obtaining the imaginary part $X_i(k, t)$ of the 15 Fourier coefficients by multiplying the new second subtraction signal with a third constant value,

20 wherein the addition signal generated recursively by the recursive processing means is a signal obtained by summing up a signal obtained by multiplying the second subtraction signal obtained before a sampling period with a fourth constant value and the second subtraction signal obtained before two sampling periods.

25 12. A recursive discrete Fourier transformation device where in data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1), x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N is a positive integer which is 1 or more) each having an equal interval are supplied and as a complex Fourier coefficient under degree k (k is 0 or a positive integer smaller than N) 30 obtained by, with such N data values supplied since time t as a data stream, carrying out complex Fourier transformation on the data stream, a real part $X_r(k, t)$ and an imaginary part $X_i(k, t)$ are obtained, the discrete Fourier transformation device comprising:

35 a data updating means for obtaining a first subtraction signal by subtracting data $x(t)$ supplied before N sampling

period from data $x(t+N)$ supplied at time $t+N$;

a recursive processing means for obtaining a new second subtraction signal by subtracting an addition signal generated recursively using an already generated second subtraction signal from the obtained first subtraction signal; and

5 a multiplying means for obtaining the real part $X_r(k, t)$ of the Fourier coefficients by summing up a signal obtained by multiplying the new second subtraction signal obtained by the recursive processing means with a first constant value 10 and a signal obtained by multiplying the second subtraction signal supplied before a sampling period with the second constant and for obtaining the imaginary part $X_i(k, t)$ of the Fourier coefficients by multiplying the new second subtraction signal with a third constant value,

15 wherein a transfer function $H(z)$ for the data updating means, the recursive processing means and the multiplying means connected as subsidiary components is given according to a following equation.

$$H(z) = A \left(1 - z^{-N}\right) \left\{ \frac{\cos \left[2 \frac{\pi k}{N}\right] - j \sin \left[2 \frac{\pi k}{N}\right] - z^{-1}}{1 - 2 \cos \left[2 \frac{\pi k}{N}\right] z^{-1} + z^{-2}} \right\}$$

20 where A is a positive constant value for providing $[x(t+N) - x(t)]$ with an amplitude.

13. A recursive discrete Fourier transformation device as claimed in claim 12 wherein the positive constant value 25 A for providing with an amplitude corresponding to a difference between the $x(t+N)$ and the $x(t)$ is capable of being set selectively with 1, an inverse number of square root of N or $1/N$.

30 14. A recursive discrete Fourier transformation device wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1)$.

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- $x(t+N)$ sampled at times $t, t+1, t+2, t+3, \dots, t+N-1, t+N$ (N is a positive integer which is 1 or more) each having an equal interval are supplied and with such N data values supplied since time t as a data stream, complex Fourier transformation
5 is carried out to the data stream using a plurality of degrees k (k is 0 or a positive integer smaller than N) so as to obtain real parts $X_r(k, t)$ and imaginary parts $X_i(k, t)$ as plural sets of complex Fourier coefficients, the discrete Fourier transformation device comprising:
- 10 plural data updating means corresponding to the plurality of degrees k , for obtaining a first subtraction signal by subtracting data $x(t)$ supplied before N sampling period from data $x(t+N)$ supplied at time $t+N$;
- 15 plural recursive processing means corresponding to the plurality of degrees k , for obtaining a new second subtraction signal by subtracting an addition signal generated recursively using an already generated second subtraction signal from the obtained first subtraction signal; and
- 20 plural multiplying means corresponding to the plurality of degrees k , for obtaining a real part $X_r(k, t)$ of the Fourier coefficients by summing up a signal obtained by multiplying the new second subtraction signal obtained by the recursive processing means with a first constant value and a signal obtained by multiplying the second subtraction signal supplied
25 before a sampling period with the second constant and for obtaining an imaginary part $X_i(k, t)$ of the Fourier coefficients by multiplying the new second subtraction signal with a third constant value,
- 30 wherein the addition signal generated recursively by each of the plural recursive processing means is a signal obtained by summing up a signal obtained by multiplying the second subtraction signal obtained before a sampling period with a fourth constant value corresponding to each degree k , and the second subtraction signal obtained before two sampling periods.

15. A recursive discrete Fourier transformation device
as claimed in claim 14 wherein the quantity of the degrees
k is N.

5 16. A recursive discrete Fourier transformation device
wherein data values $x(t), x(t+1), x(t+2), x(t+3), \dots, x(t+N-1),$
 $x(t+N)$ sampled at times t, t+1, t+2, t+3, ..., t+N-1, t+N (N
is a positive integer which is 1 or more) each having an equal
interval are supplied, data $x(t)$ supplied before N sampling
10 period is subtracted from data $x(t+N)$ supplied at time t+N
so as to obtain a first subtraction signal, and with such N
data values supplied since time t as a data stream based on
the obtained first subtraction signal, a complex Fourier
transformation is carried out to the data stream using a
15 plurality of degrees k (k is 0 or a positive integer smaller
than N) so as to obtain real parts $X_r(k, t)$ and imaginary parts
 $X_i(k, t)$ as plural sets of complex Fourier coefficients, the
discrete Fourier transformation device comprising:

20 plural recursive processing means corresponding to the
plurality of degrees k, for obtaining a new second subtraction
signal by subtracting an addition signal generated recursively
using an already generated second subtraction signal from the
obtained first subtraction signal; and

25 plural multiplying means corresponding to the plurality
of degrees k, for obtaining a real part $X_r(k, t)$ of the Fourier
coefficients by summing up a signal obtained by multiplying
the new second subtraction signal obtained by the recursive
processing means with a first constant value and a signal
obtained by multiplying the second subtraction signal supplied
30 before a sampling period with the second constant and for
obtaining an imaginary part $X_i(k, t)$ of the Fourier coefficients
by multiplying the new second subtraction signal with a third
constant value,

35 wherein the addition signal generated recursively by
each of the plural recursive processing means is a signal
obtained by summing up a signal obtained by multiplying the

second subtraction signal obtained before a sampling period with a fourth constant value corresponding to each degree k, and the second subtraction signal obtained before two sampling periods.

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17. A recursive discrete Fourier transformation device as claimed in claim 16 wherein the quantity of the degrees k is N.